APPENDIX A

APPENDIX A

Flow Net Theory

BASIC THEORY

Flow net theory is based upon Darcy's law

$$q = K \frac{\Delta H}{\Delta l} \qquad (1)$$

q= volumetric flux,

K= hydraulic conductivity,

ΔH= change in hydraulic head, H, between two points

Δl= pathlength between points at which hydraulic head was measured.

The volumetric flux, q, can also be written

$$q = Q/A \qquad (2)$$

Q= flow rate of fluid,

A= bulk area perpendicular to flow path,

and

$$Q = KA \frac{\Delta H}{\Delta l} \qquad (3)$$

Now consider the flow illustrated in Figure A1.

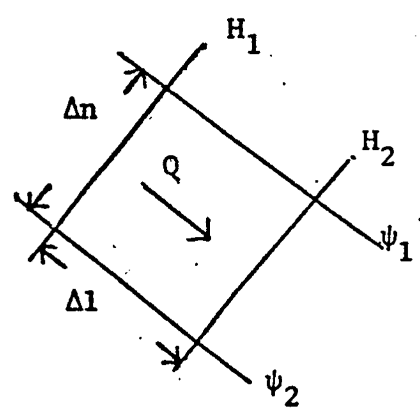

Figure A1. Flow field.

ψ_1, ψ_2 are called streamlines while H_1, H_2 are equipotential lines. If the aquifer width is one foot, the flow area, A, is simply Δn.

If the soil is assumed to be homogeneous and isotropic i.e., K is the same in all directions and at all locations. A flow net can be drawn such that $\Delta n \approx \Delta l$ and

$$Q = K \Delta H.$$

In this case, the volumetic flux, q, is in the same direction as the hydraulic gradient, $\Delta H/\Delta l$, thus streamlines are perpendicular to equipotential lines.

ANISOTROPY

If the soil is anisotropic, K is not the same in all directions but is directional. Usually K_H (hydraulic conductivity in the horizontal direction) is the maximum value of hydraulic conductivity while K_V (hydraulic conductivity in the vertical is the minimum. Because of these directional properties of hydraulic conductivity, the volumetric flux may not be in the same direction as the hydraulic gradient. Therefore, streamlines may not be perpendicular to equipotential lines. (In anisotropic soils, a streamline will be perpendicular to equipotential lines only if the hydraulic gradient is in the same direction as a principal hydraulic conductivity (K_H or K_V).

STRATIFICATION

In many cases, layered or stratified soils exist such that the thickness of these layers is much more than that of bedding planes considered to cause anisotropy. Each individual layer may be either isotropic or anisotropic within itself.

If each layer is considered to be isotropic, hydraulic conductivity is the same in all directions within the layer but with different hydraulic conductivities, then streamlines will be perpendicular to equipotential lines. However, if the flow net in any one layer consists of squares, the flow net in any other layer will consist of rectangles.

This is because at the boundary between any two layers, the streamline (and equipotential line) is refracted and a change in direction of the streamline occurs. (See Figure A2).

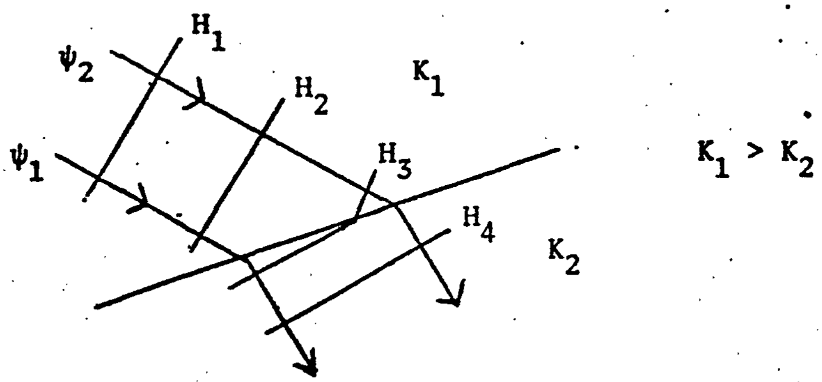

Figure A2. Deflection of streamlines at boundary between two layers.

In order to develop a flow net for each layer of a stratified material, the grid system of piezometers must be fine enough to describe the flow within each layer. However, installing a grid system fine enough to describe this flow may be neither practical nor feasible.

If the dimensions of the stratifications are small compared to the overall dimension of the flow system being studied, a stratified soil can be replaced by an equivalent homogeneous, anisotropic system (Bear 1971; Corey, 1969). The principal hydraulic conductivities of the equivalent system are mean values of the principal hydraulic conductivities (K_H, K_V) of each layer. For the equivalent system, the flow lines will not be perpendicular to the equipotential lines unless the flow direction is parallel to the direction of a principal hydraulic conductivity.